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HOVERING CRAFT & HYDROFOIL

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First Hovering Craft & Hydrofoil Monthly in the World

NEWS SUPPLEMENT

NOVEMBER, 1961

One of three Supramar PT20s operating on a 24-hour schedule to carry oilworkers to drilling sites on Lake Maracaibo, Venezuela. Since July 1960 they have carried nearly 100,000 passengers. A report on the operation to date appears on page 2 of this issue.

HOVERCRAFT TRIALS UNIT FOR ROYAL NAVY

THE Admiralty has made public recognition of the military possibilities of hovercraft. An inter-Service hovercraft trials unit is to be set up at H.M.S. Ariel, the Fleet Air Arm airfield at Lee-on-Solent, Hants.

The first hovercraft to be tested will be the SR.N2 developed by the Saunders-Roe division of Westland Aircraft. The craft is not yet in service but is expected to be operational next year.

An Admiralty statement said that the future of hovercraft in many military roles (anti-submarine and amphibious warfare, logistic support of Army units, air-sea rescue, mine-hunting and coastal forces duties) would depend on the sea-keeping ability ultimately achieved by the craft.

Information gleaned from the trials during the next two years will be shared fully with the R.A.F. and the Army.

"Preliminary studies and assessments indicate that there is a good prospect that the seaworthiness of hovercraft can be developed to such an extent as to enable them to be used satisfactorily in operational conditions," said the Admiralty.

The slipway and airfield at H.M.S. Ariel are also being made available for use by hovercraft constructed for experimental use by industry. Amongst these will be the Britten-Norman Cushioncraft.

The Admiralty appears to have fixed the hovercraft's place in the Royal Navy. They will be treated as ships, and will be commissioned with a commanding officer and driven by a coxswain.

HYDROFOIL AUTOMATIC CONTROL SYSTEM

AWARD of a contract to study automatic control systems for hydrofoil vessels has been made to the Autonetics Division of North American Aviation Inc. by the U.S. Navy's Bureau of Ships.

The purpose of the study, to be made by the Armament and Flight Control product branch, is to determine the best system for a 100-ton and a 300-ton hydrofoil vessel.

With the high speeds being considered for submerged foil vessels, automatic controls must respond with lightning-fast rapidity on a continuous basis. The control systems under study by Autonetics are intended to hold vertical accelerations to a minimum and prevent damage to the vessel when operating in waves running to 12 feet in height. They are said to be similar in principle to the autopilots designed by the company for aircraft and missiles.

SR.N2 TRIALS

THE SR.N2 Hovercraft, built by the Saunders-Roe Division of Westland Aircraft, in association with Hovercraft Development, left its hangar at Cowes, Isle of Wight, for the first time on November 20th, for initial engine runs. It will probably make its first operational run before the end of the year. The SR.N2 is designed to carry a payload of 27 tons at a cruising speed of 70 knots and a hoverheight of 1 to 1.5 ft.

HYDROFOIL CRAFT — VENEZUELA

DRILLING personnel at work on the underwater concessions of Compania Shell de Venezuela in Lake Maracaibo sometimes have to travel up to 35 miles by water to drilling locations. In order to speed up the conveyance of these oilfield workers to the sites, three 71ft. x 16½ft. x 8½ft. 50-passenger capacity hydrofoil launches were built for Shell by Werf Gusto, Schiedam, in Holland, to Supramar's PT20 design, and have been in service since July, 1960. They have accumulated approximately 6,000 hours' operational service and transported a total of 95,000 passengers.

Besides the three hydrofoil craft, a local commercial operator, "Naveca," at Maracaibo, operates three PT20 single-screw craft similar to the Shell craft, and two twin-screw PT50 craft, a much larger type, on a regular passenger ferry between Maracaibo and Cabimas.

Shell have submitted the following report on their fleet of passenger craft:

"All our service with these riveted aluminium craft has been on the Lake of Maracaibo, and being an inland sea of major geographical dimensions, it is often rough at times and therefore tests the seaworthiness of all small craft.

"The foils, with a maximum beam width of 24ft. 8in., are made of stainless steel and insulated from the hull to obtain the maximum protection against electrolytic action.

"The passenger compartment has forced ventilation and all passengers are facing aft. This we consider safer in case of collision or sudden deceleration: however, safety belts are not required.

"The normal cruising speed of our units, using a single Mercedes-Benz 12-cyl. four-stroke double supercharged marine diesel engine (Type M.B.-820 Db) giving 1,000 metric b.h.p. at 1,500 r.p.m., is approximately 35 knots. A Zahnrad Fabrik Friedrichshafen reverse reduction gear type B.W.800 is used.

"Under our conditions the Mercedes-Benz guarantee a life of 5,000 hours between overhauls.

"Our launches as well are equipped with an auxiliary "Schottel" propeller unit, which consists of a G.M. 4-cyl. two-stroke diesel type 4061A engine, developing 100 b.h.p. under our conditions driving a swivelling 360 deg. propeller mounted on the transom through an electric clutch. This auxiliary Schottel propeller can be lowered to propel the launch back to base at a speed of 4½ knots, should any inconvenience arise. Also this Schottel is used in close-quarter manoeuvres.

"We operate these craft from a central point and the furthest point is approximately 34 miles away, so that all drilling locations, platforms, tenders or other floating equipment can be reached within an hour.

"All approaches to barges and drilling platforms are made under all-weather conditions, as crews have to be relieved on a continual shift basis.

"We consider that as a result of less pounding and exhaust back-pressure noise, speed and travelling-time, manoeuvrability and handling and other related factors, the operator's and passenger's fatigue in craft of this type is greatly reduced.

"Our local crews have adapted themselves well to the handling of this type of craft, and although senior and experienced men were selected, only a short training exercise was necessary. The high speed of operation of these launches makes it imperative that the coxswain and his crew maintain a constant look-out when under way.

"We operate these launches on a 24-hour schedule, and to ensure optimum visibility a double set of headlights is fitted on the bow, giving a five/six-boat-length range of vision. This permits full speed to dead stop operation without danger of accident should any obstacle suddenly appear in the launches' course.

"The design of our wheelhouse is such that visibility is near to perfect, and being isolated from the passenger cabin, no distraction of attention of crews is possible. The coxswain and his assistants ensure that passengers remain seated during the trip and while the craft is manoeuvring.

"Economically, a 50-passenger hydrofoil launch is about as expensive to run as two normal 25-passenger capacity displacement launches, with the difference that the first one is nearly twice as fast. The advantage is in the shorter travelling times of the workers and their supervisors.

"Furthermore, we found, in general, that the riding comfort is much better in a foilborne craft than in a normal displacement launch. From experience we know that our hydrofoils maintain their speed of 35 knots through most weather conditions with waves up to 4ft. high, which is an impossibility in the case of normal launches.

"Of course, we have experienced a few operational and mechanical mishaps, but none of them have caused personnel injury or placed the launch in a nautically unsafe condition.

(a) Aground at full speed

"One day, when returning to base with only a few passengers on board, the captain obviously realised that he was in shallow water and, following his natural reaction, as he would on a displacement craft, throttled back. This resulted in more draft and consequent grounding. The web adjusting bracket attached to the trunnion tube of the forward foil was torn from the bulkhead mounting, but no damage was experienced on the stainless steel foils or other parts of the craft.

"As all passengers sit facing aft, the force of deceleration as experienced at such times causes no accident or personal inconvenience.

(b) Tree trunk on front foil

"During a normal-crew change trip one of our launches was noted to develop a slight tendency to lose lift at top speed and drop from the foil. On lifting, it was found that she had a log of 14in. diameter and 5ft. 6in. long embedded on the foil just below the full-speed water line draft.

"This mishap occurred without the apparent awareness of the operator and least of all of the passengers.

"We have had other smaller and varied shaped wooden debris attach to the forward foils, which, depending on the location on the foil, have caused impairment of the craft in becoming foilborne.

"Regarding mechanical failures, we experienced some on the main propulsion equipment, such as main-shaft of clutch shearing, disc-plates of clutch disintegrating, but none of these breakdowns have caused operational difficulties which would affect the safety of the craft.

"On several occasions we have lost the lower section of the rudder, but although the turning circle and close-area manoeuvres are affected, no safety hazard arises as a result of such a loss.

TRAFFIC BILL CONTROLS USE OF HOVERCRAFT

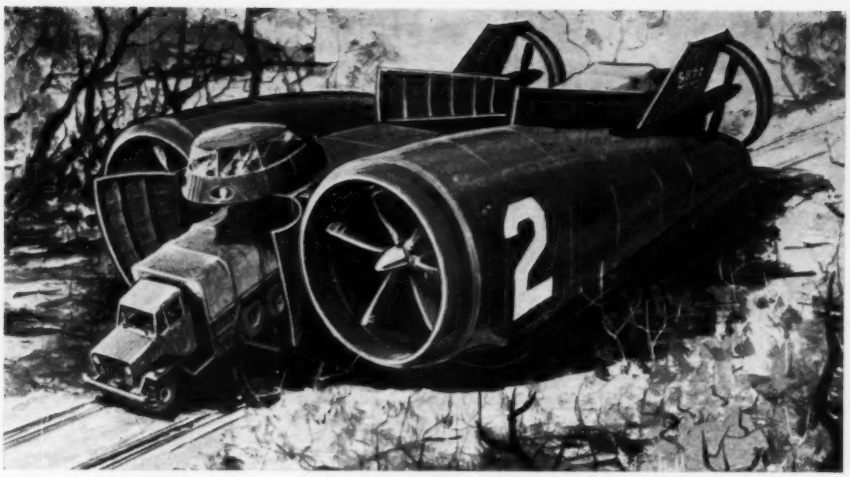
THE Road Traffic Bill published in Britain on the 2nd November contains a clause controlling small hovercraft intended for use on muddy building sites. Hovercraft will be prohibited from using roads unless authorised by an order made by the Minister of Transport.

AIR CUSHION VEHICLE FOR THE WOUNDED

THE Royal Army Medical Corps is at present testing the Folland "Hoversled," which enables wounded to be collected and moved over rough ground with less suffering than that resulting from the use of stretchers. It consists of a simple platform which travels on an air cushion maintained by a motor-driven central fan and can be pushed, pulled or towed by almost any vehicle.

LOGISTICS OVER - THE - SHORE CRAFT

Design Study by Aeronutronics



A FEASIBILITY investigation of air-cushion vehicles performed by the Aeronutronic Division of the Ford Motor Company for the U.S. Army Transportation Research Command includes design studies for a utility 2½-ton truck and an 80 m.p.h. LOTS (Logistics Over-the-Shore) craft with a payload capability of 11 tons.

The proposals for the Army truck were given briefly in our last issue. The LOTS vehicle, illustrated above, employs the same basic design, but contrasting with the truck, it has a streamlined exterior.

The following LOTS vehicle design criteria were established to be used as a guide in the design study:

Payload: 22,000 lbs.
Speed: 80 m.p.h.
Ground clearance: 5 feet.
Range: 300 miles.
Grade capability: 30%.

Parametric analyses and complementary design studies were employed to evolve the air-cushion vehicle satisfying the LOTS mission. These studies generated data for cost evaluation and cost comparisons in addition to exposing the significance of design variables on vehicle payload-range-size characteristics.

The vehicle illustrated is designed for operation at 80 m.p.h. and a 5ft. clearance. It is powered by two shaft-turbine engines of 2,000 shaft horse-power. Each engine drives one fan and one propulsion propeller.

The nominal gross weight of the vehicle is 44,500 lbs., and its empty weight is 13,315 lbs., which includes 9,275 lbs. of structure, 3,270 lbs. for power plant shaftings, gearing and fans, and 310 lbs. for operator's controls, instruments, furnishings and cab. The vehicle has the following dimensions: length 59.3ft., height 17ft., width 35.7ft. Base of the vehicle, plus lifting jet area, is 1,490 sq. ft.

The annular jet nozzle encompassing the periphery of the vehicle's base can deflect when encountering obstacles. This deflecting nozzle is one foot high, which, added to the four-foot clear space beneath the vehicle, provides the five feet clearance height.

The fore and aft nozzles have variable width capability. The side nozzles contain variable angle flow directors. This variable geometry nozzle arrangement is employed to maintain minimal power requirements with changing vehicle operating weight, height and speed. Economical and efficient vehicle operation over a broad range of conditions results from the incorporation of these refinements.

Light metal alloy and honeycomb sandwich material typical of aircraft structures is employed throughout. The resulting structure is sturdy and light, and facilitates the attainment of a fairly large design payload to gross weight fraction of .5 at a range of 300 miles.

An important design feature is the ease with which cargo can be handled. Forward located clam shell doors and aft located hatch doors permit roll-on, roll-off cargo handling. Length of the cargo compartment is 42 feet, and it has a minimum clearance of 10 feet and a width of 8 feet. Two 6 x 6 Army trucks will fit in the space provided with the rear hatch open.

The almost unique operating flexibility of air-cushion vehicles is manifest in overload payload capability. Although the vehicle was designed for an 11-ton load and a 300-mile range, it can carry a 23.5-ton payload over the same distance at the same speed if limited to a 3ft. clearance height (gross weight of approximately 70,000 lbs.). There are numerous occasions when calm seas and smooth terrain allow such reduction of operating height permitting pre-planned overload type operations. Substitution of fuel for payload at the overload gross weight will give the vehicle a 2,900-mile ferry range at 80 m.p.h. and a 3ft. clearance height.

The aft-mounted shrouded propellers provide acceleration, braking and powerful direction control. At nominal gross weight the vehicle can negotiate a 24 per cent grade and accelerate to 80 m.p.h. in approximately 22 seconds. It can be brought to a stop in 218 feet from 40 m.p.h.

If permitted to move forward at a nominal speed of 5 m.p.h., the vehicle can negotiate obstacles of 6.6ft. at full gross weight. Speeds greater than 80 m.p.h. are attainable at full gross weight by lowering the vehicle's operating height.

DESIGN PROJECT FOR HOVERCRAFT TERMINAL

TIMOTHY MURGATROYD, a fifth-year Hammersmith College of Art and Building student, has completed a thesis design for a hovercraft terminal and luxury hotel at Dover. He consulted Hovercraft Developments Ltd. to obtain data relating to a machine large enough to maintain a cross-Channel passenger and car ferry service in all weather conditions, and based his design on a vehicle (which could be built by 1966) with a payload of 450 tons; a maximum capacity of 1,500 passengers and 300 cars; and an expected average load of 800 passengers (including car occupants), 200 cars and 200 tons of freight. The maximum loaded weight would be 1,000 tons.

All aspects of the terminal design are governed by speed of handling, and Mr. Murgatroyd estimates that an extra round trip each day could be completed provided ten minutes could be saved during each "turn around" period by means of a straight-through approach by the hovercraft and loading on a broad front by two levels of cars. Twenty-five minutes is the target set for loading and offloading 300 cars—an operation planned to take place simultaneously on a broad front extending the full 300ft. length of the craft on two levels.

The need for the craft to reverse is eliminated by a system of double-ended ramps, and the off-loading building would be constructed on a headland. A breakwater is necessary for rough weather conditions, and the whole building would be sited on an open coastline away from existing docks and built-up areas.

The narrow site below the cliffs would be freed by the use of a cliff-top reception area used for high-level fly-over access to the embarkation platforms, and a 200ft. tower with restaurant and observation platforms controls hovercraft movements. All levels would be linked by vertical access providing a focal point for cliff-top sightseers. Customs facilities would be sited on reclaimed land adjoining the existing Car Ferry Terminal.

The site is at the eastern docks of Dover Harbour.

DESIGN AND OPERATING PROBLEMS OF COMMERCIAL HYDROFOIL BOATS

by Baron H. von Schertel
(Supramar A.G., Lucerne)

(Continued from previous issue)

Sea Riding Qualities

Rapid connection between two points becomes meaningless unless the passenger can rely on the timetable. In other words, transportation must be regular and not be subject to frequent interruptions on account of bad weather. Also the movements and accelerations of a vessel caused by adverse weather conditions must be considered. If they assume proportions which affect the passenger's comfort, speed must be reduced.

It has already been stated that the problem of rapid transportation on the water cannot be solved by planing boats on account of their buffeting in a seaway. At the cruising speeds which are here under consideration, actual accelerations of 6 g and more have been measured in such vessels, accelerations which may be endured for a short time by the crew of a naval craft but which exclude the use of such boats in commercial operation.

Principally it can be stated that hydrofoil boats are able to maintain a higher speed level in a seaway than any other waterborne craft of similar size. Based on practical experience, Fig. 4 shows the approximate size of waves in which hydrofoil boats of the Schertel-Sachsenberg system can still remain foilborne. The lower curve represents wave amplitudes at which the boats can operate at full power, while the upper curve shows wave sizes at which a somewhat reduced cruising speed can be maintained, which, however, keeps the vessel still in foilborne condition. The diagram permits the estimation of the size of hull which is required for operation in waves of known sizes. With a new type of foil system which is presently being developed, the limits indicated in the diagram will be considerably widened.

Riding comfort in any watercraft is of course affected by the extent of its movements in a seaway. Pitching, heaving and rolling motions of hydrofoil boats are generally much smaller than those of even-sized conventional boats. It can also be stated that the amplitude of these motions, as well as the degree of immersion in the waves, decrease with the increase of speed and of the frequency with which waves are encountered. This phenomenon in the performance of hydrofoil boats is due to a reduction of the influence of the waves on the vessel's inertia and of the orbital wave velocity on the foil's angle of incidence with the frequency of wave encounter. On the other hand, however, vertical accelerations increase with speed. In accordance with the linear theory, they increase also in proportion to the slope of the waves.

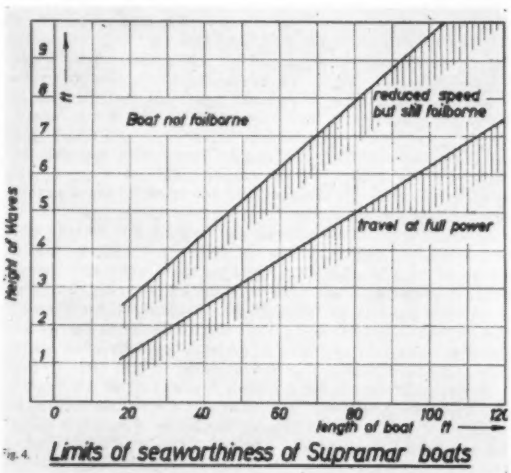


Fig. 4. Limits of seaworthiness of Supramar boats

Some indication of the extent of motion in a seaway may be gained from Fig. 5, which is based on the latest tests undertaken with a 90ft. boat in waves estimated to have reached a height of 5–6.5ft. and a length of 100–150ft. The diagram depicts the average readings of the maxima taken during a measuring period of 4 minutes. The roll angle is of course at its maximum in a beam sea. Compared with displacement boats of similar size, however, that angle is still small and the angle of pitch is very small indeed.

Diagrams 6 and 7 show the influence of speed or Froude number respectively and of wave-length on the vertical accelerations of a surface-piercing frontfoil. These diagrams are taken from a hitherto unpublished theory developed by Herr de Witt of the scientific staff of Supramar.

For the accelerations shown in the diagram the most unfavourable course of the boat in relation to the direction of the waves was assumed in each case. The fat curve in Fig. 6,

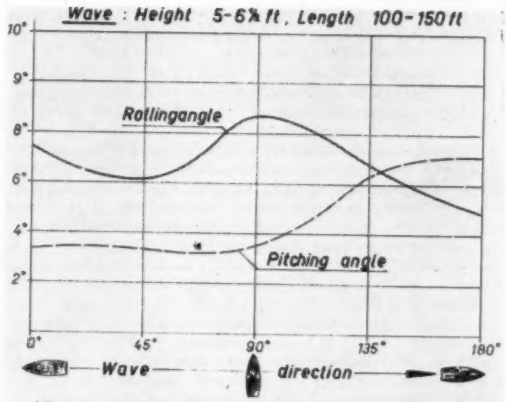


Fig. 5. Mean values for PT50 of rolling and pitching in rough water

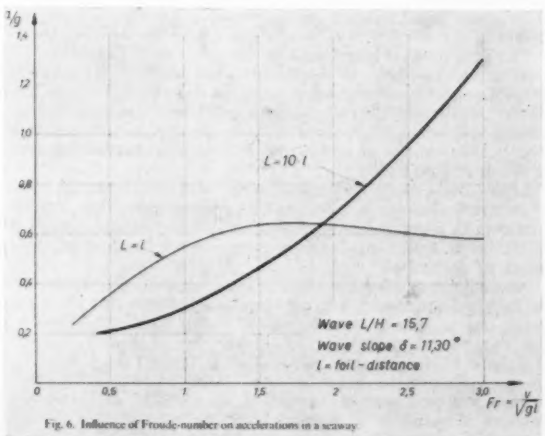


Fig. 6. Influence of Froude-number on accelerations in a seaway

DESIGN AND OPERATING PROBLEMS OF COMMERCIAL HYDROFOIL BOATS . . .

corresponding to an extremely long wave of ten times the foil distance, shows the typical increase of acceleration with increasing Froude number. Accelerations in medium waves, however, equalling the foil distance, are less dependent from the Froude number, as may be seen from the thin curve. The result of calculations represented in Fig. 7 is based on a foil distance of 66ft. and a speed of 46 knots. The height of wave belonging to each respective wave-length is shown by the dotted curve. It results that under the assumed conditions the vertical accelerations increase only up to wave-lengths which are approximately equal to the foil distance and decrease beyond that size, which is due to the decrease of the slope of the wave with its increasing length.

Fig. 8 shows the influence on vertical accelerations of the direction of travel with regard to the direction of waves for

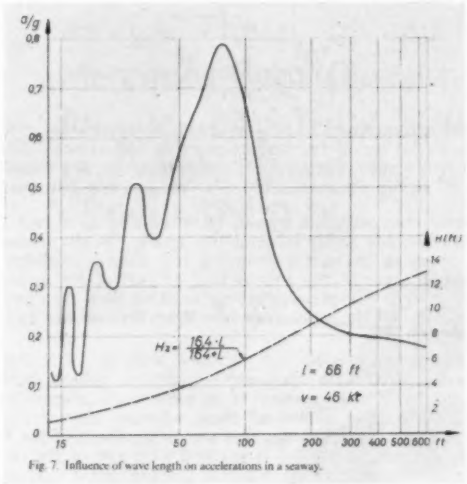


Fig. 7. Influence of wave length on accelerations in a seaway.

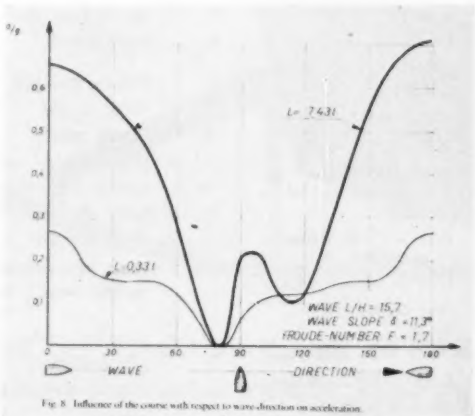


Fig. 8. Influence of the course with respect to wave-direction on acceleration.

two different relations of wave-length to foil distance. Under the given conditions (L/H = 15,7; F = 1.7) the maximum values are attained against the sea and with a following sea, whilst at a course of about 80 degrees there develops a situation where the boat remains always at the same place in the wave, which results in the disappearance of accelerations.

Basic Foil Systems

Having examined the suitability of hydrofoil craft for commercial transportation in general, we shall now consider the main design problem in hydrofoil engineering, i.e. the foil system itself, as it naturally has a decisive influence on the all-round performance of the craft. Since it is not the purpose of this paper to present a survey of all the various designs already in existence, we shall limit the discussion to the two basic foil systems which during recent years frequently formed the subject of discussions and led to differences of opinions between the experts. We shall also consider their possible future application.

A. Surface-piercing hydrofoil systems.

The surface-piercing systems consist either of single V-shaped foils or of a combination of smaller foils arranged one on top of each other in the shape of a ladder. A deviation from the equilibrium of the craft causes a change of the wetted lift-producing area of the foil and automatically creates restoring forces. The system therefore is automatically stable.

B. Fully submerged hydrofoil systems.

Fully submerged foils have no sufficient self-stability. Depth of immergence must be maintained by means of mechanical, electrical or other controlling devices which—measuring the distance between the hull and the water surface or foil-submergence—give signals to contrivances which in turn affect the lift by changing the angle of incidence of the foil or of flaps at its trailing edge.

We shall now compare drag and behaviour of the two basic foil-systems.

(a) Drag/Lift ratio.

We shall assume equal speed (45 knots), equal aspect ratio of $A = b/c = 8.3$ and a suitable foil section for either type. An average submergence ratio of $h = 1.2\ c$ is provided for the dihedral surface-piercing foil (lowest point $h = 2c$) in accordance with the boats which are at present in operation, and a lift-coefficient of only $C_L = 0.22$ with respect to aeration.

The fully submerged foil, however, requires a submergence ratio of not less than $h = 2c$ in order to avoid an excessive approach to wave-troughs, but it is permissible to apply a lift-coefficient of 0.26 since this foil is not exposed to air-entrainment, and only cavitation by influence of orbital motion has to be considered.

The total drag of a hydrofoil system may be expressed as

$$D = C_D \cdot S \cdot q$$

where S = projected foil area and q = dynamic pressure. The drag coefficient is composed of four main components

$$C_D = C_{D_i} + C_{D_O} + C_{D_W} + C_{O_{pa}}$$

wherein:

$$C_{D_i} = C_L^2 \Big/ \pi A = \text{minimum induced drag}$$

for infinite submergence. When approaching the water surface an additional influence has to be considered.

$$C_{D_O} = C_{D_f} + C_{D_{pr}} = \text{section drag.}$$

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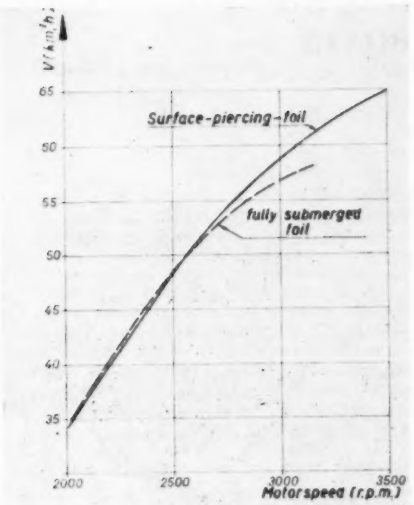


Fig. 9 Trial-boat with two foil-systems

The frictional component C_{D_f} is strongly dependent on roughness of foil surface. For smooth conditions and the applicable section thickness ratios of 0.05–0.10, skin friction drag amounts to over 90% of section drag, so that the pressure drag $C_{D_{pr}}$ is very small.

For the determination of section drag mostly results of experiments are used. C_{D_O} of a V-shaped foil with a dihedral angle w is increased to

$$C_{D_{O_w}} = C_{D_O} / \cos w$$

due to the increased length of wetted surface

C_{W_D} = wave drag

is negligibly small for high Froude number hydrofoil boats

$C_{D_{pa}}$ = parasitic drag

which refers in this case to the foil struts, piercing the water surface. V-shaped foils with their tips above the water surface during traved permit the use of relatively narrow struts, since the produced transversal forces can be taken up by structural elements which remain above the water surface when the boat is travelling in foilborne condition. Because the struts are only little immersed at cruising speed, the parasitic drag of the foil is small. The fully submerged foil, however, requires very long struts which, in view of the existing bending moments, must also be rather wide, thus causing a considerable parasitic drag which compensates the more favourable hydronamic qualities of the straight fully submerged foil.

Evaluation of the four drag components for the given example and on the assumptions stated above yields a lift/drag ratio for the surface-piercing foil of 6.9% and for the fully submerged foil of 6.7%. Towing tank results obtained from two model foils of the two systems confirm the theoretical analysis. They both produced drag/lift ratios of approximately 7%. In conclusion, we can thus consider the two basic foil-systems as being equally favourable in regard to resistance at design cruising speed.

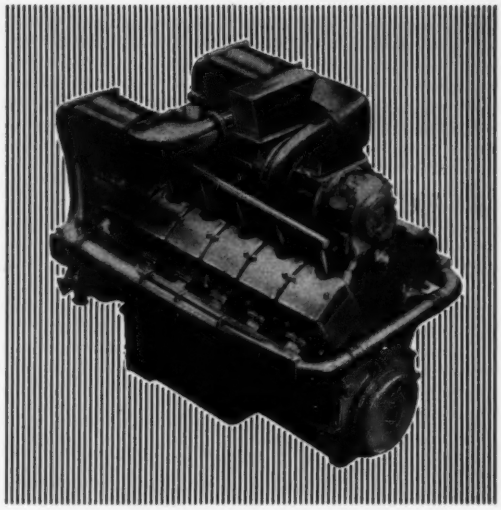
In travelling beyond cruising speed, however, the conditions change in favour of the surface-piercing foil system. The area of the fully submerged foil is determined by the capacity of take-off at the attainable $C_{L\,max}$ value. The lift coefficient decreases then with the square of speed and as a rule attains an unfavourably small value at top speed. On the other hand, when speed of the surface-piercing foil exceeds cruising speed the wetted areas of the foil as well as that of the appendages (struts emerge completely) are reduced to such an extent that their frictional drag becomes less than that of the fully submerged foil.

Experiments carried out recently with a 1 t test boat originally fitted with surface-piercing foils which were later replaced by a new system of automatically controlled submerged foils, also confirmed these inherent characteristics of the two types. Fig. 9 shows that a cruising speed of the boat of about 50 km/h. (27 knots) is reached with any of the two foils at the same engine speed, whereas the top speed attained with the surface-piercing foil is 65 km/h. (35 knots) as against 59 km/h. (about 32 knots) with the fully submerged foil.

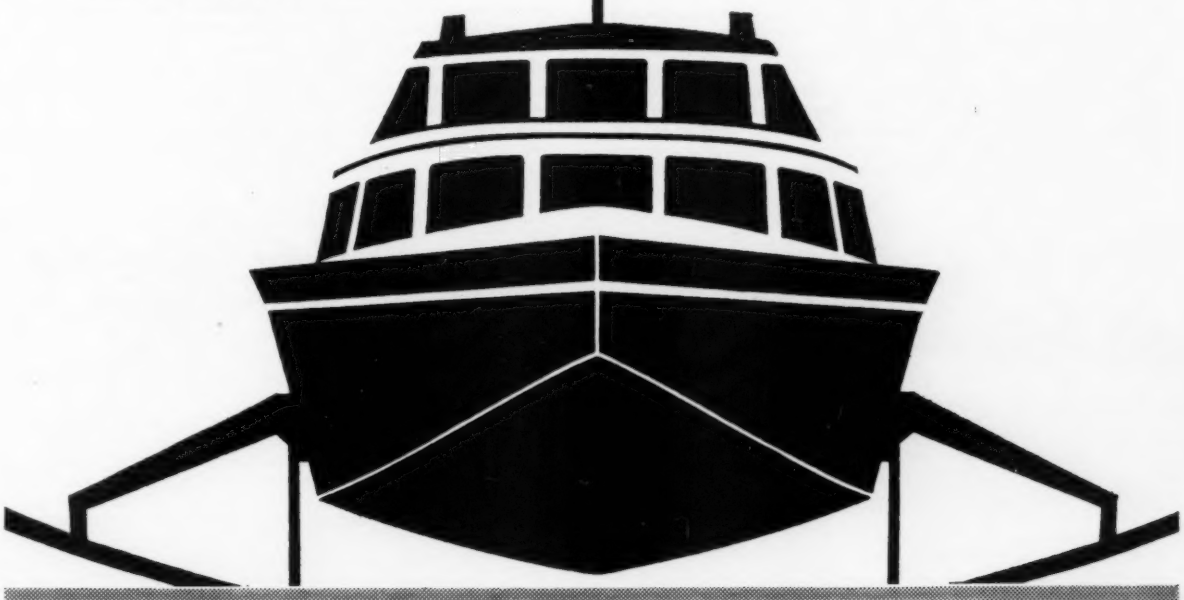
List of Symbols

a = vertical acceleration.
b = span of hydrofoil.
c = chord of hydrofoil.
h = submergence below water surface.
l = foil distance.
w = weight.
v = speed in ft/sec. or in knots.
q = $0.51\ \rho\ v^2$ = dynamic pressure.
A = b^2/S = aspect ratio.
B = fuel consumption.
CD = D/qS = drag coefficient.
CL = L/qS = lift coefficient.
D = drag of hydrofoil.
L = lift of hydrofoil.
L_W = wave length.
F = Froude number.
H = wave height.
N = motor power.
S = projected foil area.
W = orbital sensitiveness.
Z = wing characteristic.
$\triangle$ = displacement.
α = angle of incidence.
μ = weight density of water.
w = dihedral angle.
δ = wave slope.
ρ = μ/q = mass density.

FACTS SPEAK FOR THEMSELVES



... and the facts behind Mercedes-Benz Diesel engines are impressive evidence of their quality. Nearly all the world's hydrofoils, for example, are equipped with Mercedes-Benz: and these high-duty vessels demand a propelling unit which combines unusually high horse-power with a lightweight, compact design. These, of course, are the precise qualities of the MB 820 Db and the reason Mercedes-Benz Diesel type vessels of the more conventional type have also discovered the qualities for its popularity. Other of the MB 820 Db.



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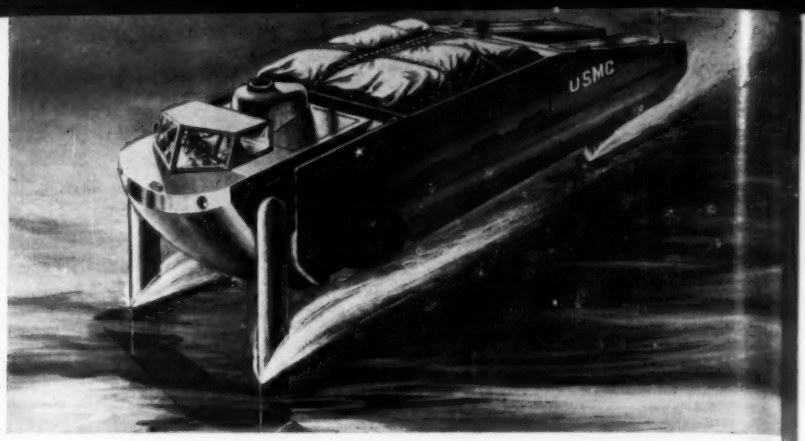
MERCEDES-BENZ

New Hydrofoil Landing Craft For Marines



The U.S. Navy's newest amphibious landing craft, the gas-turbine powered LVH. Water speed will be 45 knots, and the speed overland will be 25 m.p.h.

AVCO CORPORATION'S Lycoming Division in Connecticut has been engaged in amphibious vehicle and hydrofoil activity for several years, dating back to World War II, when it built for the military a then secret high-speed craft known as the "Salamander" or "X Craft." This vehicle was of a track-laying amphibious tank design, capable of moving through water and on land at speeds up to 20 m.p.h. Two such vehicles were built using a Lycoming O-435-T engine as the power plant. Production of the vehicle was never released due to the termination of hostilities.

Designed only to test the feasibility of some advanced hydrofoil designs, Lycoming's "Halobates" was flown successfully in 1959 at a speed in excess of 35 m.p.h. A T53 engine was provided for a Navy LCVP which was converted to a hydrofoil configuration.

The "Flying Duck" project which followed (conducted by Lycoming for the Government under contract with the U.S. Army Ordnance Corps) was the design and development of a "one only" gas turbine powered hydrofoil version of the famed World War II DUKW which proved the principle of the turbine-hydrofoil marriage.

Combining an 860 horse-power Lycoming T53 engine with aerodynamically shaped hydrofoils, the craft proved its ability to "take off" and operate successfully in rough water at speeds in excess of 35 m.p.h.

In August, 1961, the U.S. Navy asked Lycoming to design and develop an amphibious landing craft—a gas turbine powered hydrofoil craft with fully submerged foils capable of transporting several thousand pounds at speeds up to 45 knots through rough seas.

Known technically as the LVH or Landing Force Amphibious Support Vehicle Hydrofoil, it is designed to be used by the Marine Corps in a logistic role during landings. Specifically its mission is to transport cargo during the assault phase of an amphibious operation from widely scattered LSTs, LSDs and LPDs off-shore. It must be capable of "flying" through rough water, boating through the surf zone and traversing difficult beaches, sand dunes and other rough terrain normally encountered in an off-road operation, reach an unloading point and then return to ship.

The new Lycoming TF-1430 marine gas turbine engine, which can operate on a variety of fuels, makes possible "flying" speed in excess of 35 knots, boating speed of several knots and overland speed of more than 25 miles per hour. All dimensions were designed so as to allow operations from virtually any Navy ship.

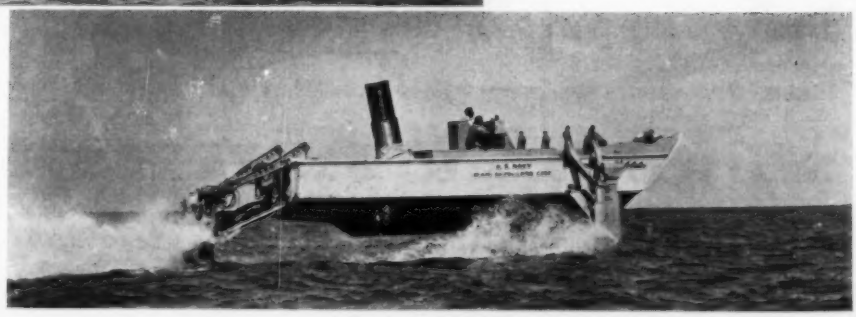
Several unique features have been incorporated into the LVH. The hydrofoils, one forward and one aft, are of high aspect ratio design and are completely submerged during all water operation. For land travel, they are retracted entirely within the confines of the hull. The foils are self-cleaning and have been designed to operate through floating debris without damage.

Separate propellers are included for boating and "flying" operations. The "flying" propeller is mounted on the forward portion of the bottom of the rear strut. The centre lower section of the strut, including the foil and propeller, is rotatable to provide dynamic steering. The boating propeller is separately mounted on a retractable drive beneath the hull.

The four huge 18:00 x 25:00, 12-ply tubeless, self-sealing tyres are mounted on fully retractable wheels for boating and "flying" operations. Power steering of the front wheels is provided. The tyres incorporate Schrader inflation systems which permit inflation or deflation from within the cab while under way.

Terms of the contract call for delivery of the first of the new craft in January 1963. Initial qualification tests will be performed in Long Island Sound off Stratford. Government tests and evaluations will be conducted at the Marines' Camp Pendleton, in California.

The "Flying Duck" proved the principle of turbine-hydrofoil marriage. This converted World War amphibious DUKW operated at more than 35 m.p.h. as compared to its previous speed of 6 m.p.h. It first "flew" in 1959.



"Halobates," a converted Navy LCVP, was the world's first turbine-powered hydrofoil boat. Powered by a Lycoming T53 gas turbine engine, the craft "flew" successfully at speeds in excess of 35 m.p.h. in sea trials starting early in 1959.

CONTROL SCHEME FOR AERONUTRONIC'S ARMY UTILITY TRUCK

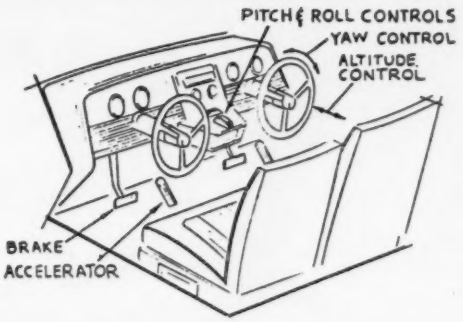
FOR the 2½-ton utility truck designed by the Aeronutronic Division of the Ford Motor Co., and described briefly in our last issue, great importance was attached to ease of operation. Consequently, all control schemes were based on the premise that operators would have little more training than that required by Army truck drivers.

The drawing below is one of several control arrangements devised for the craft. There is an accelerator, brake pedal, and a steering wheel for directional control. The wheel, in addition, moves in or out as an altitude control. Pitch and roll control requirements are considered to be trim controls rather than a primary flight control. As such, small trim wheels mounted on the central console are sufficient for pitch and roll, since they need be adjusted only at the beginning of a mission and perhaps periodically adjusted during the mission.

Rapid response to the controls of a vehicle of this type is considered vital, since drivers will be called upon to negotiate unfamiliar terrain at speeds of about 40 m.p.h.

The truck brakes by reversing the pitch of the propulsion fans and converting the available power in excess of that required for lift into reverse thrust. In addition to the powerful braking force made available in this way, the aerodynamic drag helps to decelerate the vehicle.

In a paper presented to the SAE International Congress earlier this year, Mr. Murray F. Southcote, of Aeronutronics, said that the air-cushion vehicle is capable of braking performance like that of automobiles in everyday driving circumstances. This capability is considered to be adequate for an air-cushion vehicle operating in off-road terrain.



NEW PASSENGER HYDROFOILS

NORTHWEST HYDROFOIL LINES, of Seattle, Washington, has applied to the U.S. Government for mortgage insurance under Title XI of the Merchant Marine Act of 1936, covering the construction of two 75-passenger hydrofoil ferries to be placed in service in Puget Sound and vicinity.

The two ships will cost a total of $1.4 million. They will be 75½ feet in length and have a beam of 16½ feet. A 2,250 h.p. gas turbine engine will give these ferries a speed of some 40 knots. Designs call for three separate passenger areas: a passenger deck forward to accommodate 12 passengers, an after-deck compartment to accommodate 48, and a main deck compartment that would seat 25. A transverse stairway will connect the passenger deck to the main deck. In addition there will be a baggage compartment and a small galley.

The specification also calls for adjustable reclining seats, air conditioning, and picture windows with tinted anti-glare safety glass to provide full visibility for passengers.

DENISON PROGRESS

THE H.S. Denison ocean-going hydrofoil, under construction by Dynamic Developments Inc., is now in its final stages of completion. It is expected that a six-month test and evaluation programme will begin later this autumn.

The ship has been moved from its building site at Bethpage, New York, to its launch site at Jacobsen's Shipyard at Oyster Bay, Long Island, New York, a distance of ten miles. Its gas turbine engine has been installed and portions of the transmission. The main hydrofoils are being completed and will be installed on the vessel within the next few weeks.

The craft is planned as a forerunner of future commercial craft. Various regulatory groups, such as the U.S. Coast Guard, American Bureau of Shipping, Federal Communications Commission, and U.S. Salvage Corporation, have been invited by the U.S. Department of Commerce's Maritime Administration, who are sponsoring the craft, to observe the constructional progress and to comment where appropriate. Assistance from these groups has been most helpful in planning for future commercial craft, says the Administration.

After testing, the ship will be assigned to one of twenty-eight companies that have applied to the agency for operation of the craft in short-range passenger service.

PROPOSAL FOR BRISTOL CHANNEL HOVERCRAFT SERVICE

MR. S. C. SMITH COX, Managing Director of P. & A. Campbell Limited, Cardiff, the second British company intending to operate overwater passenger Hovercraft services, made the following statement to "Hovering Craft and Hydrofoil" recently:

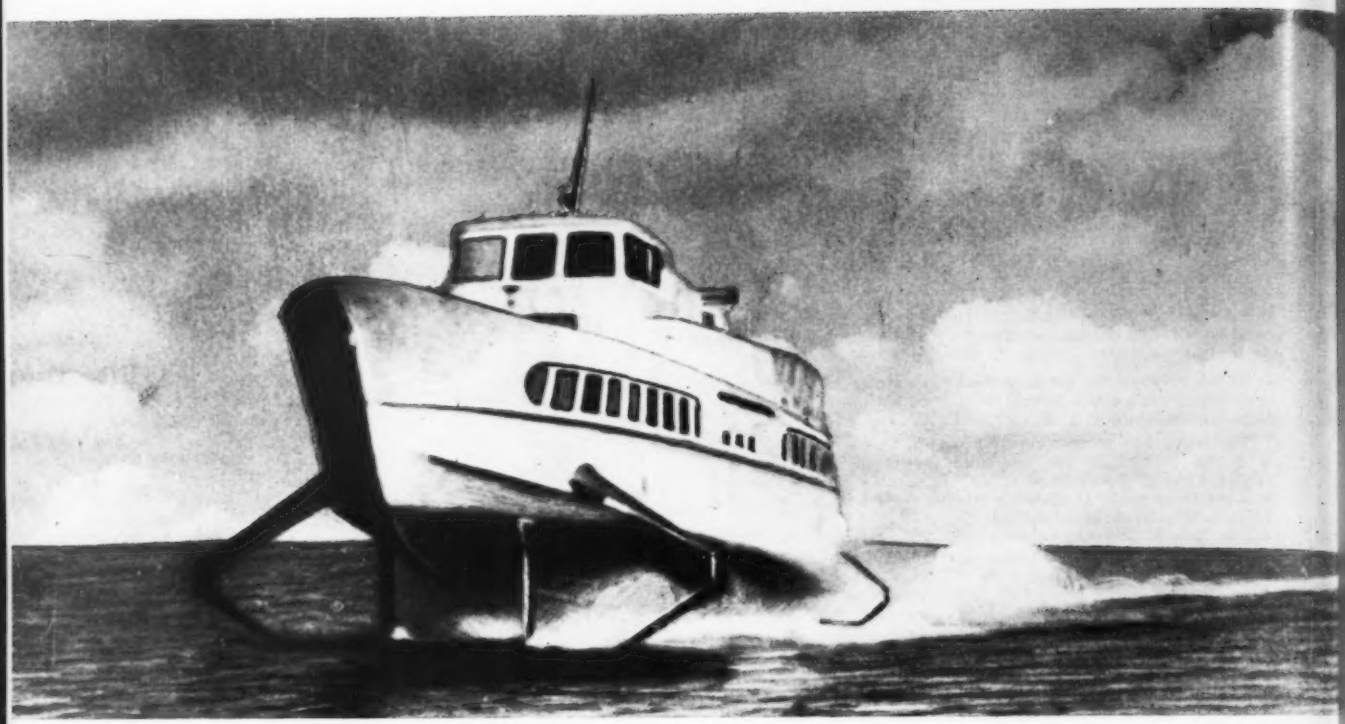
"The Bristol Channel has presented problems to those who have wished to cross it as long as history has been written in this country. The Channel has the second highest tidal rise and fall in the world; a matter of 48 feet on the occasion of certain spring tides, and as its banks slope very gently seawards the water recedes in most places a very considerable distance. Well before the war the question of a possible car ferry service across the Channel was considered, but never came to fruition. Since the war it has been repeatedly suggested, but the cost of harbour works which would be necessary to enable the sea crossing to be made with regularity would be prohibitive.

"Those who have crossed from Somerset to South Wales by steamer will have noticed on many occasions how fast the tide drops, and may often, when they have been on the pier at Weston-super-Mare, have observed that the water has receded altogether, and there is a vast expanse of land where, at high tide, there was sea. This fact precludes, except at prohibitive cost, the provision of a regular car ferry service by sea. The same fact, however, makes possible the provision of a car ferry service by Hovercraft.

"Passengers travelling from Devon to South Wales who wish to cross from Weston to Cardiff would clearly only do so if they were ensured that a regular ferry service operated. If they had to rely on the tide and could travel only during certain hours each day (these hours on each occasion differing) the service would be unsatisfactory.

"Hovercraft opens up the possibility of this problem being overcome. A craft capable of conveying approximately 20 cars or 200 passengers, or a combination of both, would appear to be necessary for the service from Cardiff to Weston. For other services which the company hopes to develop, it may be necessary for further advances to be made, having regard to the weather conditions encountered in the more exposed parts of the Channel.

"We have now made an application to the Air Transport Licensing Board to operate Hovercraft in the Bristol Channel. Our sister company, Townsends Ferries and Shipping Ltd., who operate the cross-Channel Dover-Calais car service, are also intending to operate Hovercraft on this route."



Russia's first sea-going hydrofoil is the Mir, a 92-passenger craft which recently completed trials in the Black Sea. It is a scaled-down version of the Cosmos, now under construction.

RUSSIA BACKS BIG HYDROFOILS

SOVIET interest in hydrofoil vessels is understandable in view of the enormous length of her inland waterways. Many of these are shallow, if only along certain parts of their length, while others are comparatively narrow, or of artificial construction (canals), which means that it is desirable that wash shall be kept down to a minimum, as can be done without loss of speed only by the use of hydrofoils (or, of course, of hovering craft, which are outside the scope of this article). Consequently Soviet ship and boat builders are devoting a lot of attention to the design and construction of hydrofoils of various sizes, the building of which has been concentrated at the "Krasnoye Sormovo" shipyard at the important industrial centre and river-port of Gorki, on the Volga.

The largest of these is the Sputnik, described by a correspondent in Pravda as having seating for 300 passengers—twice as many as has the earlier Meteor, described later in this article—and weighing less than one-thirtieth as much as a three-decked river-boat of the conventional type with the same passenger capacity. It is also very much faster (43.5 knots), and much more economical in fuel consumption. Full details of this type are, unfortunately, not yet available, but the craft was described at the time of her maiden voyage, in October, when she covered the distance between Gorki and Moscow, about 560 miles, in 14 hours, as being 93ft. 2.5in. (50 metres) in length and weighing 110 tons, with her full complement of passengers, and as having four engines, developing a total of over 3,000 h.p. Low weight is achieved by the use of aluminium-magnesium alloy for the hull and, together with plastic materials, for the superstructure, and by having an all-welded hull (in the earlier types the hull is riveted).

A vessel of equivalent size but of stouter construction, and correspondingly somewhat heavier, was seen on the stocks by the Pravda correspondent who reported the Sputnik. It was described to him as being designed for use on the large lakes of the U.S.S.R., which are virtually "seas," and in coastal waters. This is now known to be the Cosmos, of which a smaller prototype, carrying 92 passengers, the Mir, recently completed successful trials in the Black Sea. These are described as having foils made of high-tensile stainless steel, presumably to enable them to stand up, as claimed, to weather up to strength 4, and would seem to be slightly faster (46.6 knots). Their engines are remote-controlled from the wheelhouse, which is fitted with an automatic helmsman, for emergencies.

Going up the scale through its predecessors, one comes first to the Raketa type, of which a large number are now operating regularly on all the major rivers of the U.S.S.R., including the great rivers of Siberia, which are of rapidly increasing importance, and which have shallow and narrow tributaries. This type, which has seating accommodation for 66 passengers, is propelled by a diesel engine developing 900 h.p. at 1,650 r.p.m. It has a maximum speed of nearly 40 knots, and a cruising speed of 33.5 knots, with the engine developing 650 h.p. at 1,200 r.p.m. At this speed the fuel consumption is only about 635 lb. for 100 miles (170 kg. for 100 km.) and the range is 466 miles (750 km.). The principal particulars are as follows:—

Length o.a.	27m. (88ft. 7in.)
Extreme breadth	5m. (16ft. 5in.)
Max. draught when floating at full displacement	1.8m. (5ft. 11in.)
Max. draught when of hydrofoils	1.1m. (3ft. 7in.)
Total displacement	24 tons
Useful load	6.5 tons

Next comes the Meteor, put in operation on a regular service on the Volga, between Moscow and Gorki, in the summer of last year (1960), of which a dozen or so are now working on the major rivers of the U.S.S.R. It is much larger than the

RUSSIA BACKS BIG HYDROFOILS . . .

The 300-seat Sputnik, which made its maiden voyage in October, planing back to moorings on the Volga.

Raketa, having seating accommodation for 150 passengers, and slightly faster, its twin screws, driven by two diesel engines, each developing 850 h.p., giving a speed of 43.5 knots (maximum speed, 49.7 knots), at which speed it has a range of 373 miles (600 km.). It is estimated that its cost of transportation per passenger is about one-third of that of a conventional river vessel of corresponding capacity, and its larger size, as compared with the Raketa, is reflected in improved amenities for passengers. The principal particulars are as follows:—

Length o.a.	34.4m.	(112ft. 10in.)
Breadth at deck	6m.	(19ft. 8in.)
Breadth inc. rubbing strake ...	8m.	(26ft. 9in.)
Depth	2.2m.	(7ft. 3in.)
Overall height above water when foilborne	6.8m.	(22ft. 4in.)
Draught when foilborne ...	1.2m.	(3ft. 11in.)
Draught when floating ...	2.3m.	(7ft. 6in.)

The adoption of an all-welded hull for the Sputnik and Cosmos presents the advantage, of course, of facilitating sectional construction. Thereby, as was pointed out to Pravda by the authorities at the Krasnoye Sormovo shipyard, doubling the importance of that shipyard on the Volga. Already the national centre for the design and development of hydrofoil vessels, it will henceforth be also a centre from which prefabricated sections of such vessels will be sent, for assembly, to other shipyards in various parts of the U.S.S.R., special mention being made of Batumi (Batum), on the Caspian, in this connection.

Some hints of what may be expected to emerge from this very active shipyard in the future may be gathered from the Pravda correspondent's references to a new hydrofoil vessel for 30 passengers, with a cruising speed of 62.5 knots, on which work is now in progress, and to completed blue-prints of a variety of other hydrofoil vessels, including cargo-carriers (sea-going and for use on inland waters) and even ocean-going liners, in some of which higher speeds are to be achieved by the introduction of gas-turbines in place of diesel engines. The naval architect responsible for this programme is a young man called Rostislav Yevgenievich Alexev, who designed all the vessels described in this article.

At the other end of the scale, and for some time already in series production, are water-taxis and runabout pleasure craft, such as the Molnia (Lightning) exhibited at Earl's Court in July, 1961. This runabout has accommodation, in an open cockpit, for six passengers, including the coxswain, and is propelled by a petrol engine developing 80 h.p., coupled through a reversible angle reduction gear with a single propeller. It has a cruising speed (in calm water) of 40.4 knots, and a range of 90 miles. The principal particulars are as follows:—

Length o.a.	8.48m.	(27ft. 9in.)
Total breadth	1.65m.	(6ft. 5in.)
Depth amidships	0.98m.	(3ft. 3in.)
Max. draught when foilborne ...	0.55m.	(1ft. 9in.)
Max. draught when floating ...	0.85m.	(2ft. 8in.)
Total displacement	1.75 tons	

Many hundreds of these handy little runabouts are now in use all over the U.S.S.R., including, it is interesting to know, Lake Baikal, in Siberia, which has been developed as a popular summer resort, to which Russians fly.

Molnia (Lightning)—a six-seat runabout with a speed of 40 knots and a range of 90 miles.

CUSHIONCRAFT READY FOR SOLENT TRIALS

AFTER fifteen hours' flying on the airfield at Bembridge, Britten-Norman's Cushioncraft is moving into its second phase—overwater trials. The Air Registration Board have inspected it and will recommend the issue of a permit by the Ministry of Aviation. Based from Bembridge Harbour, the trials will be carried out over the Solent.

Britten-Norman are pleased with its progress and report that control and stability have been quite up to expectations.

The machine will be on view at the Daily Express Boat Show in January, where it will be described as a "family-size" hovercraft.

SEAGOING HOVERING CRAFT PLANNED BY UNITED STATES

THE U.S. Maritime Administration is negotiating a contract with the Vehicle Research Corporation of Pasadena, California, for the design of a "surface-effect" ship. The Douglas Aircraft Company will be the main sub-contractor involved, it is reported.

Providing for design and model studies, the programme envisages a full-scale experimental craft being built in 1962.

NEW HOVERCAFT SUBSIDIARY FORMED

TO continue the Company's work on Hovercraft development, William Denny & Brothers Limited have decided to form a wholly-owned subsidiary company. This company, called "Denny Hovercraft Limited," has now been formally registered in Edinburgh.

The new company has taken over part of the Leven Shipyard adjoining the Old Dock, including the Beam Shed and Electrical Cable Store. New offices have been erected on this site.

Because of the nature of the work involved, the new company will operate as a boat-building company, and will apply for membership of the Scottish Ship & Boat Building Employers' Association. This point has been explained by the directors to the convener and sub-convener of the shipyard shop stewards, and the Board are glad to record the shop stewards' agreement that the new company would receive all help and co-operation in its efforts to bring more employment to Dumbarton.

As soon as the new premises are nearing completion, it is hoped to start recruiting a small labour force.

Plans are in hand to start construction of four passenger-carrying Hovercraft developed from the experimental craft D1, which has been undergoing trials over recent months.

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Lord Carrington, First Lord of the Admiralty, boarding the SR.N1 Hovercraft for a trial run during his visit to the Saunders-Roe Division of Westland Aircraft Limited in early November.

300 TON HYDROFOIL FOR U.S. NAVY

THE Grumman Aircraft and Engineering Corp., Bethpage, Long Island, have been awarded a 11.8 million dollar two-phase contract by the Navy Bureau of Ships for the development of a hydrofoil research ship to evaluate hydrofoil design and test its application in anti-submarine warfare.

The 300-ton, 200-foot vessel will be able to ride above the waves at 50 knots and will be capable of speeds up to 85 knots an hour.

The first stage of the contract involves the design and planning of the vessel at a cost of $1,597,781. The second stage calls for its construction at a cost of $10,309,134, in conjunction with a commercial shipbuilder. Building is expected to start by the middle of next year.

PUBLICATIONS RECEIVED

A NEW 24-page colour brochure on the 150-passenger hydrofoil motor ship Meteor has been issued by the Soviet export organisation, "Sudoimport." A photograph of the craft was published in our October issue.

The Meteor is powered by two 12-cylinder M50 water-cooled, supercharged V-type engines, with a normal service output of 900 h.p., and a maximum output of 1,200 h.p. Each engine drives its own propeller shaft, and the twin screws are contra-rotating.

Controls are all situated in a small wheelhouse set above and at the rear of the fore saloon. Aircraft styling is used in the wheelhouse, which is in effect a one-man flight deck. The throttles are of dual-lever aircraft type.

The Meteor's hydrofoil arrangement consists of two sets of foils, one set at the bow and one at the stern, plus two subfoils set on the side stanchions of the bow foil. The foils are described as being flat, with a rather pronounced convex cross-section in the centre. The bow foil is attached to the hull by two side and one keel stanchion, and the stern foil by two side stanchions. The stanchions are of a split type and the foils are secured to them by flanges and bolts, an arrangement which permits the foil angles to be adjusted by the insertion of wedges between the flanges and the foils.

The Meteor's hull is integral with the superstructure, and with the exception of small exposed areas fore and aft, has no main deck. The hull is framed on the combined longitudinal and transverse system, and both hull and superstructure are of riveted construction. Only the steel members have been welded. Hull and superstructure are built in duraluminium.

The Meteor will seat 150 passengers on what are described as "suburban" services, while a second version, termed a "transit" design, seats 130. Normal cruising speed of the craft is given as 43.5 knots.